Pertinence of Irisiome Lasers for Quantum Applications

Introduction

As recently highlighted by the 2022 Nobel prize in Physics - Alain Aspect, John F. Clauser and Anton Zeilinger - Quantum technologies have to mature to ensure a fast and efficient transition between fundamental research at the highest level and the quantum technology market. In the field of pure photonics single photon production schemes which are a key element for most practical applications, the front head laser source is strategic. Irisiome has developed a line of compact and robust industrial lasers, quasi maintenance free, acting like true "photo guns" at very high rep rate. This technology can be seen as the true workhorse able to address issues from application-oriented research and industrial R&D all the way to a highly interconnected, agile operations.

The Pulse Gating Technology

Among all the existing technologies that enable delivering short and ultrashort pulses, electro-optic pulse gating technology is one of the most versatile and user-friendly methods. Combining the advantages of hyper-frequency electronics and lasers to generate ultra-short laser pulses, this approach is based on the gating of pulses by an optical intensity modulator seeded by a continuous wave laser (see Figure 1). The new ultrashort pulse generator developed by Irisiome allows the tunability of the pulse duration down to tens of picoseconds to any pulse duration with optical spectra limited by Fourier Transform, keeping very long coherence length. Moreover, the repetition rate can be adjusted very precisely and in a very wide range up to few GHz. Since pulses are only controlled electronically, external synchronization to a RF signal or another device is easy.

Pulse gating technology is completely achromatic and can be used with a wide range of continuous near infrared laser sources.

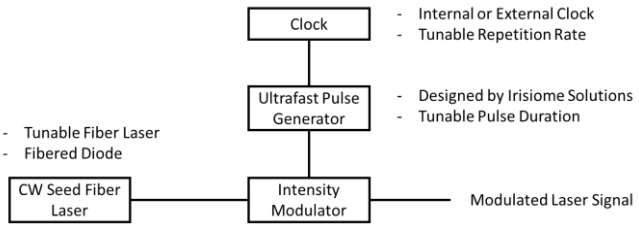


Figure 1: Ultrafast Pulse Gating Diagram Developed by Irisiome.

The master oscillator used upstream of the modulators is based on laser diode technology, which offers very high spectral coherence and a line width of a few megahertz.

In addition, fiber amplifier technology makes it possible to amplify over a spectral window of tens of nanometers, making fine wavelength tunability possible (see example in Figure 2).

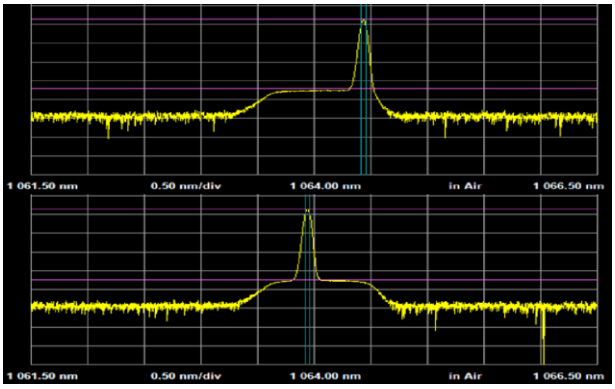


Figure 2: Example of Fine Tunability near 1064 nm.

After the ultrashort pulses have been generated by pulse gating the continuous wave diode, the amplified master oscillator architecture, known as MOPA, enables the delivery of average powers up to 30W. The MOPA structure is made of optical fibers, which makes it extremely efficient at carrying and amplifying light. This results in a laser beam that is highly linear and uniform in both polarization and spatial properties (Figure 3). Polarization-maintained single-mode fiber typically yields a perfectly Gaussian profile (TEM00) with an M^2 <1.1, a circularity greater than 90% and a polarization rate greater than 20 dB (i.e. 1: 100). These quality parameters are crucial in the

laser selection because the laser is placed at the front end of important installations, and often used in complex interactions (frequency conversion, amplification, etc.).

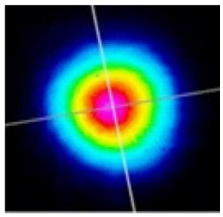


Figure 3: Example of Output Beam Profile of an Irisiome Solutions Laser Based on Pulse Gating Technology.

For the highest power levels, the use of large core optical fibers and free-space optics may slightly deteriorate the beam profile and its circularity, but while still maintaining an M^2 of less than 1.3 and a circularity greater than 85%.

This fully-fiber MOPA architecture, which takes advantage of polarization-maintaining large-core optical fibers, allows the propagation of high-peak power pulses. This enables a solution that is both effective and easy to use.

The technology of fiber amplifiers enables the delivery of energies of up to several millijoules, limited by the amplifier material. The peak power of the pulses is limited to several hundred kilowatts by non-linear effects and the confinement of the beam in the fiber core. It is possible to obtain pulses with energies from a few hundred picojoules up to several hundred microjoules, with a pulse peak power of up to several hundred kilowatts.

Figure 4 demonstrates the levels of average powers maintained on a large pulse repetition frequency for different versions of the MANNY integrating a pulse gating system.

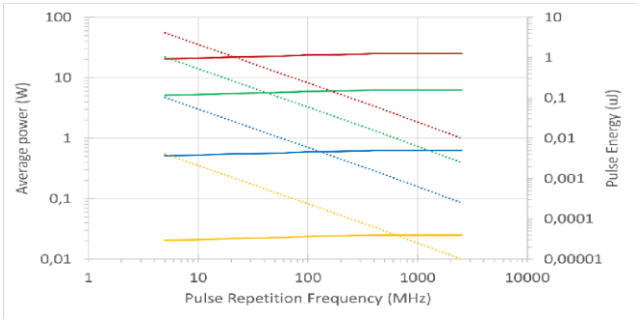


Figure 4: Example of Energy and Average Power Reached with Various MANNY Laser Versions.

Irisiome Solutions' laser architecture is a fully integrated system that enables a high degree of stability over time (see Figure 5) and very low maintenance, making it ideal for continuous industrial applications. This rugged industrial equipment does not require specific technical skills in laser technology, unlike other available solutions. The stability of these systems that are based entirely on electronic instructions is largely dependent on external parameters, such as the quality of the control and synchronization electronics.

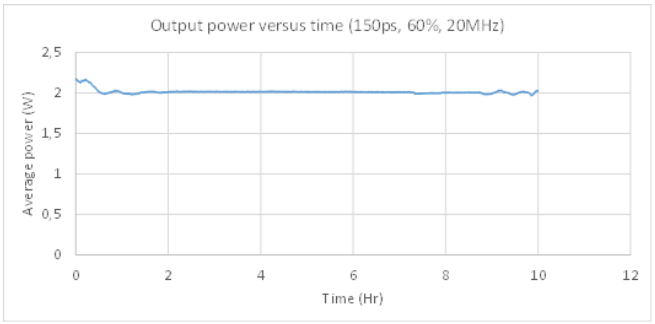


Figure 5: Example of Stability of Average Power Over Time Obtained with an Irisiome Solution System.

About IRISIOME

IRISIOME is a French start-up company from Bordeaux in France founded in 2015. The company is the result of a project valorization led by the CELIA Laboratory (CEntre Lasers Intenses et Applications) whose purpose was to develop a user-friendly and simple laser source for medical applications. Since the beginning of the project our team has strengthened its expertise by developing an innovative laser architecture which would easily be integrated in any experiment or system. Willing to widen its offer and put its laser sources to the test of challenging applications. IRISIOME has created a new brand, IRISIOME Solutions, fully dedicated to the scientific and R&D markets. We stand ready to take up any challenge and new developments that. will push our systems to the highest level of performance to comply with our users' specific requirements. Today our lasers are used in many routine applications.

For more information, you can visit our website (http://www.irisiome-solutions.com) or contact us at contact@irisiome-solutions.com

IRISIOME SOLUTIONS

Key Advantages for Quantum Technology

The advantages of Irisiome lasers based on pulse gating technology make them the perfect match ++for quantum applications.

1. Precise Tailored Pulses

Pulse gating technology is capable of generating watt-level pulses down to tens of ps. When lower pulse durations are needed, it is possible to reach the sub-picosecond regime by generating non-linear effects in long optical fibers. The optical spectrum can be broadened to a few nanometers using polarization-maintaining single-mode fiber operating in the normal dispersion regime. Then, ultra-short pulses can be retrieved using standard compression techniques[1].
The Irisiome Solutions Peaches series is a turn-key system designed for quantum applications that uses pulse gating and optical compression technology to generate precise pulses with durations between 500 fs and 35 ps. (see Figure 6). The technology enables a very low timing jitter, which is perfect for synchronization in quantum technologies.

2. Large Wavelength Tunability

Irisiome Solutions systems provide a wide variety of infrared wavelengths. By adding a second harmonic generation module, visible wavelengths are also accessible. The Peaches series offers standard wavelengths like 1µm and 1.5 µm, as well as 920 nm which is of real interest for quantum applications. The seeder also has the potential to tune CW laser IR wavelengths by tens of nanometers. This tunability is very interesting for pumping quantum dot based single photon sources for example. Tuning the wavelengths in the IR also allows expanding the visible range by making many wavelengths available on the 455 – 785 nm range. In order to be suitable for any quantum application, there is ongoing research to extend even further the tunability in the visible range in the future.

PEACHES SERIES
Compact Ultrafast Fiber Laser for Quantum Applications

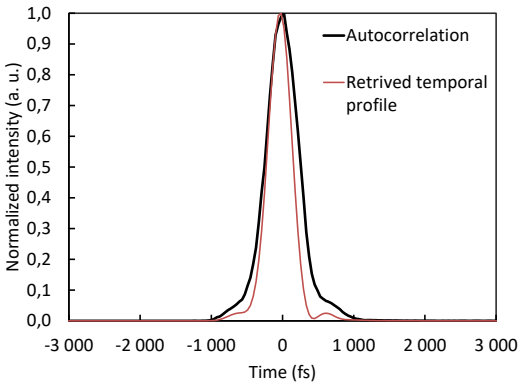
PEACHES product range integrates an innovative electronical pulse generation system which delivers from femtosecond to tens of picosecond pulses.
The repetition rate is continuously adjustable on a high range, up to the GHz regime. Lasers from the PEACHES series can work with arbitrary pulses sequences in external synchronization mode for “photon gun” applications.
For a even more flexible system, the wavelength can be optionally tunable for standard wavelengths used in Quantum applications around 920 or 1550 nm for example.
PEACHES systems fit perfectly any industrial and scientific application that requires master/slave synchronization and small footprint.

Key Features of Peaches Laser from Irisiome Solutions:

- Tunable and Adjustable Pulse Repetition Frequency up to 2 GHz, Burst Capability, Optional Arbitrary Pulses Sequences
- Many Wavelengths Available : 460 - 515 - 530 -670- 775 - 780 -920 - 1030- 1064 - 1550 nm, Slightly Tunable, MHz Linewidth
- Ultrashort Pulse Duration from 500 fs to 35 ps
- Multistage Fiber Amplifier up to 30 W
- Compact, Turn-key Master/Slave System

[1] William Renard *et al* 2022 *Laser Phys. Lett.* **19** 075105

(a)



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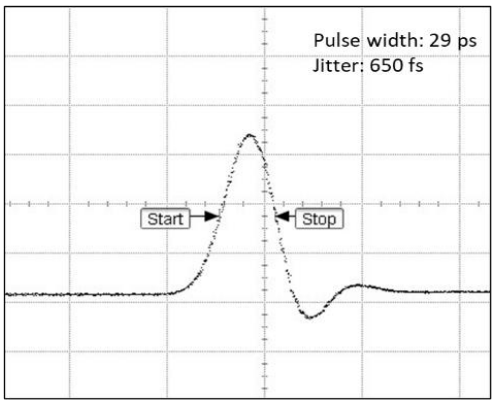

Figure 6: Typical (a) 500 fs and (b) 29 ps Temporal Profile Obtained with Pulse Gating Technique.

3. Real « Photon Gun » Capability with Arbitrary Pulses Sequences

Many technologies in the quantum-enabled future, such as quantum communications, rest on an elusive goal: finding technologies that can pump out identical single photons with well-defined optical properties on demand, to perform the so-called quantum encryption. This will ultimately remove one of the final obstacles keeping perfectly secure messages from being sent over standard telephone fibers.

The general proprietary laser architecture of IRISIOME LASERS fully relies on a triggering device, a key issue to fulfil such a strong requirement.

Our approach appears to be the easiest way to generate any arbitrary sequence of single photons similar to the graph in Figure 7.

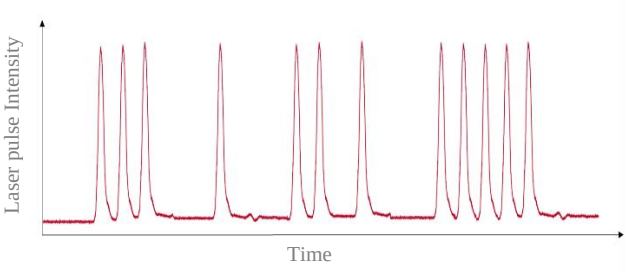

Figure 7: Example of Random Laser Pulse Sequence.

4. Full Phase Control within the Whole Pulse Train

Our unique technology based on a seeding device that can be chosen with the smallest bandwidth ensures a very good and stable phase control over the entire train of amplified pulses (see Figure 8).

This will be of major interest for all phase resolved quantum experiments such as entanglement and phase dynamics.

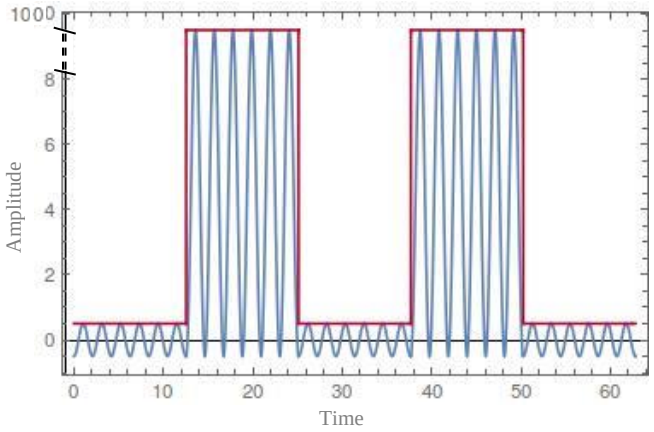

Figure 8: Illustration of gating as a function of the phase.